

**ATTACHMENT C**

**TECHNICAL MEMORANDUM**

**BANK EROSION BED ELEVATION STUDY  
TITTABAWASSEE RIVER**

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## Draft Memorandum

DATE: November 27, 2006

PROJECT: ATSTR

TO: **Phil Simon, Peter  
Simon, ATS** FROM: **Tim Dekker, Ph.D., P.E. - LTI  
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CC: File  
SUBJECT: **2005 Data Collection and Analysis  
Bank Erosion Bed Elevation Study, Tittabawassee River**

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### Introduction

The second annual round of elevation surveys was performed in November and December 2005 along predetermined transects at three study areas ([Figure 1](#)) along the Tittabawassee River. This memorandum provides documentation of the following:

- Field activities performed to collect the 2005 transect elevations, and
- 2005 transect survey data, along with a preliminary analysis comparing these data to the 2004 baseline survey data.

The objective of this study is to gain a better understanding of the potential erosional and/or depositional trends of the river bank and bed occurring over time in the study areas. This information is expected to contribute to evaluation of solids transport into and out of the Tittabawassee River. Survey data collected in 2005 are compared to the baseline transect survey data obtained in 2004, and these comparisons could be continued in the future if this would complement to other site activities.

Field activities were performed in accordance with the methods and procedures described in Section 4.0 of the report titled *Nonanalytical Sampling Activities for Tittabawassee River* dated November 2004. During the field activities, no changes were made to the protocols described in that document.

### Study Areas, Ground Control and 2005 Survey

The three study areas coincide with floodplain lithologic sample transect lines established in the *Floodplain Soils Pilot Study Sampling and Analysis Plan*, August 2004 (CH2MHILL). These three study areas are shown on [Figure 1](#) and are described as follows:

- Study Area 1 – Dow Property near rivermile 17.5.
- Study Area 2 – Imerman Park, just downstream of the boat launch.
- Study Area 3 – Downstream of Center Rd. at the Shiawassee Wildlife Refuge.

In November 2004, LTI staff established ground control within each study area for three transect surveys. Ground control establishes spatially fixed points for standard survey equipment (e.g., total station) to use in performing transect surveys on an annual basis. For each study area, established transects follow the same sequence: Transect B is the

most upstream transect; followed downstream by transects A and then C, respectively. A standard plan view of the ground control layout is illustrated in [Figure 2](#).

Transect surveys performed in 2005 followed the same procedures as in 2004. Using the established ground control, Wade-Trim and LTI staff jointly collected the horizontal (station) and vertical (elevation) coordinates of each survey point along each transect using total station survey equipment. To the best of their ability, 2005 survey points replicated the 2004 survey points (i.e., 2005 elevations were recorded at the same locations as in 2004 along each transect). This protocol allows for changes in elevation to be evaluated on a point-by-point basis from year to year.

The survey points for each study area are shown on [Figures 3, 4, and 5](#), respectively. [Tables 1 through 3](#) present the survey data (coordinates and elevations) for the 2004 and 2005 surveys in each study area, respectively. These tables also show the calculated horizontal and elevation changes from 2004 to 2005 for each survey point.

## Error Analysis Approach

To evaluate changes between the two surveys, it is necessary to assess whether observed changes are significantly different between the two years of observation. This assessment requires an understanding of the accuracy of the two surveys, in order to distinguish between elevation differences that are too small to be determined to be outside the bounds of survey error, versus larger differences that can be readily distinguished from survey error.

The assessment of survey accuracy includes two major sources of error: vertical error due to survey method limitations, and error in horizontal positioning that would also contribute error to the measurement of vertical position. The two elements are quantified for each measurement location as follows.

### *Vertical Survey Error*

Error in the measurement of vertical elevation arises from numerous sources, including bend in the survey rod, non-verticality of the survey rod, and inaccuracy in the rangefinder and vertical angle measurement made with the survey instrument. In the absence of specific data on the magnitude of these errors, the contributions of all these sources of error to total vertical survey error is assumed to be  $\pm 0.1$  foot.

### *Horizontal Positioning Error*

Error in horizontal positioning can contribute to error in vertical position by moving a point up or down the local slope. Consequently, this error is potentially greater in areas of high slope, such as the relatively steep banks. Mean estimated error in horizontal position is the average of the absolute values of all estimated positional errors, based on calculation of the differences between horizontal locations recorded in the two surveys:

$$\delta_x = \frac{1}{n} \sum |\delta_{xi}|$$

For each survey transect, a single estimate of mean estimated positional error is calculated for three subsets of the data: upland, bank, and in-river points.

A local slope is also calculated for each point, based on a linear regression of a three-point neighborhood (calculated with the excel SLOPE function). The slope represents a local estimate of the vertical elevation change (rise) divided by the horizontal position change (run), or:

$$m_i = \frac{\Delta z_i}{\Delta x_i}$$

Then the estimated error in the vertical elevation due to positional inaccuracy is the local slope multiplied by the mean horizontal position error, or:

$$\delta_{z|\delta x_i} = \frac{\Delta z_i}{\Delta x_i} \delta_x = m_i \delta_x$$

The two sources of error can be combined to provide an overall estimate of vertical accuracy, following a sum-of-squares convention for linear combination of error:

$$\delta_z = \sqrt{(\delta_{z|survey})^2 + (\delta_{z|\delta x_i})^2}$$

It is important to note that the error analysis methods described here are preliminary, because of the limited data (a single baseline and repeat survey) available for comparison. Error analysis and assessment of trends in bed elevation changes will be refined as future surveys become available. The following additional activities are recommended to refine the uncertainty estimates and minimize error:

- To estimate survey error, conduct same-day resurveys of selected transects and compute typical differences (e.g. root mean squared differences) for floodplain, bank, and in-river areas.
- If any future surveys are to be conducted, resurvey monuments to allow control for any movement due to settling or other disturbances,
- Limit any future surveys to a time of year when soils are not subject to frost heave.

## Data Evaluation

Survey results, calculated differences between the 2004 and 2005 surveys, and error bound estimates following the approach described above are presented in [Figures 6-8](#) for the three study areas, respectively. For each transect plot, the survey elevation data is presented in profile on the upper portion of the graphic, and the calculated elevation difference (2004 vs. 2005) is shown in the lower portion. Calculated error bounds are shown as a gray region on the plots of calculated differences. In cases where the estimated vertical difference falls within the calculated error bound, the error bound should be used as an indication of the range of possible differences. Preliminary observations for the three study areas are described below.

### *Study Area 1*

The three transects surveyed in Study Area 1 ([Figure 6](#)) exhibit some consistent features. All of the transects have a relatively steep bank, with a 10 foot drop over 20 feet of horizontal run, and an upland low area behind the top of bank. In the river, all three transects show a greater channel depth on the left (north) side of the river, with a relatively shallow shelf on the south side. This reach of the river is relatively straight, with no clear geomorphic structure (point bars or eroded banks) that can be related to river sinuosity.

The upland area surveys show a consistent rise in elevation from 2004 to 2005, although the observed increases are typically at or slightly outside of the survey accuracy bounds and do not provide a clear indication of soil accretion. The amount of leaf cover or the state of the vegetative ground cover present during the two surveys could have some impact on the results of the surveys. Transect A does show a localized elevation decrease of approximately 6 inches at the lowest upland point that is significantly larger than the survey accuracy bound.

The elevation of the bank areas along all three transects also shows a general trend of increase, with observed differences of between 0.1 and 0.5 feet between the two surveys. The observed differences are spatially variable, and like the upland survey area may be related to differences in the amount of leaf deposition, the condition of the vegetation on the banks, and possibly due to frost heave during the cold weather conditions of the second survey.

Observed changes in in-river elevations vary, from little apparent change in the right (south) side of the river, to more significant changes in the deeper portion of the channel to the north. The largest observed change is a very localized mid-channel decrease of approximately two feet at the center of the channel on Transect A. Observed differences are more typically on the order of six inches, and are spatially variable throughout each transect. The observed in-river elevation changes are consistently in the downward (erosional) direction.

### *Study Area 2*

The three transects surveyed in Study Area 2 ([Figure 7](#)) also exhibit consistent features, with relatively steep banks, an elevated top-of-bank, and an upland low area behind the bank similar to that observed in Study Area 1. In-river, the depths are greatest on the south side of the river, likely corresponding to the outer bend that passes Imerman Park immediately upstream of the study area.

Comparison of the upland area surveys indicates no significant changes in elevation, with all observed changes within the bounds of the estimated survey error.

Bank elevations show a trend of small or no increase, with observed changes only slightly outside the estimated accuracy bound. The trend of small, generally positive changes in bank elevation is consistent with observations made at Study Area 1.

In river, just beyond the bank at the north end of each of the three transects, the surveys show a consistent increase in bed elevation of 0.5 – 1.5 feet at locations with 50-75 feet of the northern shoreline. These locations correspond to the inside of the Imerman Park river bend upstream of the study area. All three transects also show a clear transition

from depositional changes at the north end to an erosional change at the south end, corresponding to the outer bend of the River upstream of the study area. Observed in-river changes in elevation at the south end are more broadly distributed, extending to about 100 feet from the south shoreline; but changes are less extreme, with observed erosion less than 1 foot in all cases.

### *Study Area 3*

The three transects surveyed in Study Area 3 ([Figure 8](#)) have similar features to those observed upstream, with a relatively small upland depression, an elevated top-of-bank, a steep bank, and a relatively level in-river elevation profile. The river has a slightly deeper channel at the left (south) side in this reach.

Similar to the other study areas, the upland area in Study Area 3 shows no significant or a small positive change in elevation, which may be a function of changes in the amount of leaf matter, vegetative condition, or frost heave.

Again consistent with the upstream study areas, measured bank elevations show insignificant or small positive increases between 2004 and 2005. Observed increases near the top of the bank on Transects A and C were larger than in the upstream areas, with increases on the order of 6 inches. No significant erosion of the banks was measured at any location over the observation period.

In-river elevations were variable across the three Area C transects, but there were significantly more areas of measurable erosion than deposition. Transect B, the upstream of the three transects, was eroded primarily at the left, or north side of the river. In contrast, the middle transect (A) was more eroded at the right (south) end of the transect, and transect B shows erosion fairly evenly distributed throughout the transect. In all cases, the amount of erosion is 0.1 to 0.5 feet, with a few locations showing erosion in the 0.5 to 1 foot range. Although the survey did identify a few depositional areas on these transects, they were very limited in spatial extent.

## **Summary and Conclusions**

In November and December 2005, LTI and Wade-Trim staff replicated the 2004 transect surveys in the pilot study areas described above. A comparative analysis of the 2004 and 2005 data indicates the following conclusions:

- Surveys of upland areas in all three of the pilot study areas indicated either no significant change or small positive changes in elevation of the ground surface. While the observed changes were consistently positive or near zero, the observed change under this first round of elevation resurvey may be related to changes in the amount of leaf matter, vegetative condition, or frost heave on the ground surface.
- Surveys of the banks in all of the pilot study areas also showed consistency across all study areas, with either negligible or small positive changes in bank elevation. Where elevation changes existed, they were typically on the order of 6 inches or less. As with the upland areas, these changes may be related to differences in leaf matter or vegetation.

- In-river elevation changes were spatially variable in the relatively straight reaches of Study Areas 1 and 3, with observed differences typically between 0.1 and 0.5 inches of negative (erosional) change. In localized areas, surveys showed scour on the order of as much as two feet in Area 1. In both of these areas, observed significant elevation changes were much more consistently negative (erosional) than positive (depositional).
- Higher flow velocities and sediment bed shear stresses are normally seen along outer bends, and lower velocities and shear stresses along inner bends. Outer bends are therefore expected to experience more erosion and less deposition over time than inner bends. In-river elevation changes in Study Area 2, located on the inside of the large river bend upstream of the study area, were consistent with this expected behavior of a river bend. All transects showed net deposition at the inside of the bend (transect north end) on the order of 0.5 – 1.5 feet, and net erosion at the south end of the transects of 1 foot or less.

The observations made under this survey are preliminary, based on a single baseline survey and a single comparison survey. We have recommended above that same-day resurveys be conducted to estimate the magnitude of survey error in floodplain, bank, and in-river areas. A comparison of elevation changes estimated in this document to those error estimates would provide a good measure of the signal-to-noise ratio in a one-year comparison, making it possible to estimate the number of years (assuming that elevation will continue to change at approximately the same rate) that would be needed to distinguish between true elevation changes and measurement error. If a resurvey were conducted at a time interval informed by that comparison, it could then contribute an independent line of evidence concerning deposition and erosion to the GeoMorphTM investigation, assuming that this timing is consistent with the overall timing of the investigation.

### **Attachments:**

Table 1	2004/2005 Survey Data – Study Area 1
Table 2	2004/2005 Survey Data – Study Area 2
Table 3	2004/2005 Survey Data – Study Area 3
Figure 1	General Location of Three Study Areas
Figure 2	Typical Control Establishment
Figure 3	Survey Points, Study Area 1
Figure 4	Survey Points, Study Area 2
Figure 5	Survey Points, Study Area 3
Figure 6	Transect Elevation Profiles, 2004/2005 - Study Area 1, (three charts)
Figure 7	Transect Elevation Profiles, 2004/2005 - Study Area 2, (three charts)
Figure 8	Transect Elevation Profiles, 2004/2005 - Study Area 3, (three charts)

**Table 1**  
**2004/2005 Survey Data - Study Area 1, Dow Property near River Mile 17.5**  
**Tittabawassee River Bank Erosion and Bed Elevation Study**

2004 Location_ID	2004 Location_Desc	2004 Survey Data			2005 Survey Data			2004 vs. 2005	
		Easting	Northing	Elevation	Easting	Northing	Elevation	Station Difference (ft.)	Elev. Difference (ft.)
FRE-03235	A1	747642.80	13175899.52	600.25	747642.63	13175899.43	600.38	0.19	0.13
FRE-03236	A2	747638.04	13175898.04	600.15	747638.12	13175898.04	600.35	0.08	0.20
FRE-03237	A3	747633.36	13175896.60	600.16	747633.44	13175896.62	600.28	0.09	0.12
FRE-03238	A4	747628.64	13175895.14	599.68	747628.69	13175895.16	599.85	0.05	0.17
FRE-03239	A5	747623.85	13175893.66	598.63	747623.96	13175893.70	598.80	0.12	0.17
FRE-03240	A6	747619.12	13175892.20	597.52	747619.30	13175892.25	597.69	0.18	0.17
FRE-03241	A7	747614.29	13175890.71	596.41	747614.29	13175890.71	596.45	0.00	0.04
FRE-03242	A8	747609.37	13175889.19	595.52	747609.36	13175889.18	595.10	0.01	-0.42
FRE-03243	A9	747604.73	13175887.75	594.90	747604.74	13175887.76	594.67	0.02	-0.23
FRE-03244	A10	747600.11	13175886.33	594.50	747599.99	13175886.29	594.55	0.13	0.05
FRE-03245	A11	747595.36	13175884.86	595.23	747595.34	13175884.85	595.19	0.02	-0.04
FRE-03246	A12	747590.16	13175883.25	595.66	747590.21	13175883.27	595.75	0.05	0.09
FRE-03247	A13	747585.45	13175881.80	596.37	747585.33	13175881.76	596.48	0.13	0.11
FRE-03248	A14	747580.89	13175880.39	598.15	747580.99	13175880.42	598.15	0.10	0.00
FRE-03249	A15 TB	747578.40	13175879.62	598.94	747578.41	13175879.62	598.96	0.01	0.02
FRE-03250	A16 TB	747571.67	13175877.54	598.90	747571.62	13175877.52	598.92	0.05	0.02
FRE-03251	A17	747570.02	13175877.03	597.85	747569.89	13175876.99	597.77	0.14	-0.08
FRE-03252	A18	747567.96	13175876.39	596.22	747568.15	13175876.45	596.50	0.20	0.28
FRE-03253	A19	747566.24	13175875.86	594.93	747566.18	13175875.84	595.21	0.07	0.28
FRE-03254	A20	747564.34	13175875.27	593.61	747564.30	13175875.26	594.14	0.04	0.53
FRE-03255	A21	747562.56	13175874.72	592.81	747562.48	13175874.70	593.23	0.08	0.42
FRE-03256	A22	747560.70	13175874.15	591.87	747560.80	13175874.18	592.25	0.10	0.38
FRE-03257	A23	747558.81	13175873.56	591.00	747558.67	13175873.52	591.25	0.15	0.25
FRE-03258	A24	747557.00	13175873.00	590.17	747556.84	13175872.95	590.40	0.17	0.23
FRE-03259	A25	747555.04	13175872.40	589.57	747554.87	13175872.34	589.77	0.18	0.20
FRE-03260	A26	747553.12	13175871.80	588.53	747553.23	13175871.84	588.66	0.11	0.13
FRE-03261	A27	747551.48	13175871.30	587.08	747551.54	13175871.31	587.34	0.06	0.26
FRE-03262	A28 TOE	747549.80	13175870.78	585.45	747549.75	13175870.76	586.06	0.05	0.61
FRE-03263	A29 H2O SURFACE	747550.36	13175870.95	586.18	747550.51	13175871.00	586.77	0.16	0.59
FRE-03264	A30	747540.99	13175868.05	584.69	747540.84	13175868.00	584.78	0.15	0.09
FRE-03265	A31	747531.02	13175865.09	584.29	747530.99	13175865.08	584.33	0.03	0.04
FRE-03266	A32	747521.29	13175861.96	583.77	747521.40	13175862.00	583.95	0.12	0.18
FRE-03267	A33	747511.41	13175858.91	584.19	747511.38	13175858.90	583.87	0.03	-0.32
FRE-03268	A34	747501.46	13175855.83	584.35	747501.32	13175855.79	584.35	0.15	0.00
FRE-03269	A35	747491.90	13175852.87	583.88	747491.77	13175852.83	583.74	0.14	-0.14
FRE-03270	A36	747482.16	13175849.88	583.61	747482.11	13175849.87	583.38	0.06	-0.23
FRE-03271	A37	747471.95	13175846.73	583.83	747472.13	13175846.78	583.38	0.18	-0.45
FRE-03272	A38	747461.85	13175843.61	583.04	747461.72	13175843.57	582.96	0.14	-0.08
FRE-03273	A39	747452.14	13175840.60	583.30	747452.10	13175840.59	582.81	0.04	-0.49
FRE-03274	A40	747442.32	13175837.57	583.76	747442.31	13175837.56	581.76	0.01	-2.00
FRE-03275	A41	747432.65	13175834.58	582.00	747432.48	13175834.53	581.74	0.18	-0.26
FRE-03276	A42	747423.75	13175831.83	583.13	747423.88	13175831.87	583.12	0.14	-0.01
FRE-03277	A43	747413.97	13175828.80	583.23	747413.85	13175828.77	583.14	0.13	-0.09
FRE-03278	A44	747397.64	13175823.76	585.03	747397.54	13175823.73	584.97	0.10	-0.06
FRE-03279	A45	747386.23	13175820.25	585.05	747386.28	13175820.25	584.98	0.05	-0.07
FRE-03280	A46	747375.71	13175816.99	584.93	747375.75	13175817.00	584.84	0.04	-0.09
FRE-03281	A47	747365.98	13175813.94	584.95	747365.99	13175813.95	584.89	0.02	-0.06
FRE-03282	A48	747356.79	13175811.13	584.99	747356.81	13175811.11	584.95	0.02	-0.04
FRE-03283	A49	747345.78	13175807.73	584.94	747345.77	13175807.70	584.85	0.03	-0.09
FRE-03284	A50	747337.13	13175804.26	584.94	747336.98	13175804.21	584.88	0.16	-0.06
FRE-03285	A51	747328.04	13175802.25	584.94	747327.88	13175802.20	584.94	0.17	0.00
FRE-03286	A52	747318.63	13175799.33	585.15	747318.50	13175799.30	585.10	0.13	-0.05
FRE-03287	A53 H2O EDGE	747314.32	13175798.01	586.36	747314.44	13175798.05	586.02	0.12	-0.34
FRE-03289	B1	747644.33	13175845.81	600.29	747644.41	13175845.83	600.43	0.08	0.14
FRE-03290	B2 TB	747639.55	13175844.34	599.74	747639.63	13175844.36	599.87	0.08	0.13
FRE-03291	B3	747634.93	13175842.91	598.11	747635.00	13175842.93	598.30	0.08	0.19
FRE-03292	B4	747630.10	13175841.41	596.77	747630.28	13175841.47	596.89	0.19	0.12
FRE-03293	B5								

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**2004/2005 Survey Data - Study Area 1, Dow Property near River Mile 17.5**  
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2004 Location_ID	2004 Location_Desc	2004 Survey Data			2005 Survey Data			2004 vs. 2005	
		Easting	Northing	Elevation	Easting	Northing	Elevation	Station Difference (ft.)	Elev. Difference (ft.)
FRE-03329	B41	747419.45	13175776.20	585.52	747419.33	13175776.29	585.38	0.15	-0.14
FRE-03330	B42	747409.93	13175773.38	585.15	747409.80	13175773.34	585.28	0.14	0.13
FRE-03331	B43	747400.05	13175770.27	585.11	747400.07	13175770.34	585.03	0.07	-0.08
FRE-03332	B44	747391.77	13175767.46	585.13	747391.73	13175767.44	585.07	0.04	-0.06
FRE-03333	B45	747381.70	13175764.33	585.12	747381.75	13175764.34	585.10	0.05	-0.02
FRE-03334	B46	747371.96	13175761.63	585.18	747371.90	13175761.28	585.01	0.35	-0.17
FRE-03335	B47	747362.75	13175758.85	584.96	747362.82	13175758.46	584.86	0.40	-0.10
FRE-03336	B48	747353.54	13175755.81	584.90	747353.77	13175755.65	584.92	0.28	0.02
FRE-03337	B49	747343.10	13175752.63	585.07	747343.27	13175752.68	584.92	0.17	-0.15
FRE-03338	B50	747333.14	13175749.66	585.33	747333.10	13175749.54	585.26	0.12	-0.07
FRE-03339	B51	747326.87	13175747.54	586.21	747326.84	13175747.60	585.76	0.07	-0.45
FRE-03340	B52 H2O EDGE	747325.30	13175747.22	586.74	747324.99	13175747.03	586.52	0.36	-0.22
FRE-03342	C1 TB	747618.78	13175937.02	600.30	747618.90	13175937.06	600.49	0.12	0.19
FRE-03343	C2	747613.97	13175935.54	599.44	747613.79	13175935.48	599.57	0.19	0.13
FRE-03344	C3	747609.25	13175934.08	597.99	747609.33	13175934.10	598.13	0.08	0.14
FRE-03345	C4	747604.46	13175932.60	596.88	747604.52	13175932.61	597.01	0.06	0.13
FRE-03346	C5	747599.80	13175931.16	595.55	747599.84	13175931.17	595.72	0.04	0.17
FRE-03347	C6	747594.98	13175929.67	594.97	747594.99	13175929.67	595.27	0.01	0.30
FRE-03348	C7	747590.24	13175928.21	594.87	747590.22	13175928.20	595.07	0.03	0.20
FRE-03349	C8	747585.45	13175926.72	595.41	747585.53	13175926.74	595.73	0.08	0.32
FRE-03350	C8	747580.69	13175925.25	596.59	747580.58	13175925.22	596.81	0.11	0.22
FRE-03351	C9	747575.90	13175923.77	597.56	747576.08	13175923.83	597.78	0.19	0.22
FRE-03352	C10 TB	747571.08	13175922.28	598.55	747570.97	13175922.25	598.70	0.12	0.15
FRE-03353	C11 TB	747562.52	13175919.64	598.73	747562.58	13175919.66	598.85	0.06	0.12
FRE-03354	C12	747560.61	13175919.05	598.22	747560.73	13175919.09	598.43	0.13	0.21
FRE-03355	C13	747558.72	13175918.46	597.50	747558.55	13175918.41	597.70	0.17	0.20
FRE-03356	C14	747556.61	13175917.81	596.31	747556.64	13175917.82	596.72	0.03	0.41
FRE-03357	C15	747554.84	13175917.26	595.23	747554.88	13175917.28	595.63	0.05	0.40
FRE-03358	C16	747553.01	13175916.70	594.49	747552.97	13175916.69	594.63	0.05	0.14
FRE-03359	C17	747551.06	13175916.10	593.23	747551.04	13175916.09	593.77	0.02	0.54
FRE-03360	C18	747549.22	13175915.53	592.62	747549.27	13175915.55	592.82	0.06	0.20
FRE-03361	C19	747547.15	13175914.89	591.78	747547.33	13175914.95	592.18	0.19	0.40
FRE-03362	C20	747545.33	13175914.33	591.15	747545.31	13175914.32	591.42	0.02	0.27
FRE-03363	C21	747543.25	13175913.68	590.44	747543.39	13175913.73	590.68	0.15	0.24
FRE-03364	C22	747541.39	13175913.11	589.70	747541.33	13175913.09	589.96	0.07	0.26
FRE-03365	C23	747539.43	13175912.51	589.01	747539.55	13175912.54	589.57	0.12	0.56
FRE-03366	C24	747537.50	13175911.91	588.66	747537.67	13175911.96	588.82	0.18	0.16
FRE-03367	C25	747535.71	13175911.36	587.99	747535.83	13175911.39	588.24	0.12	0.25
FRE-03368	C26	747533.51	13175910.68	587.18	747533.55	13175910.69	587.30	0.04	0.12
FRE-03369	C27 H2O EDGE	747532.44	13175910.35	586.76	747534.82	13175911.08	587.73	2.49	0.97
FRE-03370	C28 TOE	747530.66	13175909.80	585.18	747530.72	13175909.82	585.30	0.07	0.12
FRE-03371	C29	747518.23	13175906.04	584.15	747518.28	13175906.06	584.33	0.05	0.18
FRE-03372	C30	747508.51	13175903.11	583.84	747508.60	13175903.15	583.68	0.10	-0.16
FRE-03373	C31	747498.57	13175900.11	583.95	747498.42	13175900.06	583.61	0.16	-0.34
FRE-03374	C32	747490.01	13175897.29	583.96	747489.99	13175897.29	583.42	0.02	-0.54
FRE-03375	C33	747480.83	13175894.17	583.99	747480.75	13175894.14	583.94	0.09	-0.05
FRE-03376	C34	747471.07	13175891.50	584.06	747470.92	13175891.46	583.84	0.15	-0.22
FRE-03377	C35	747461.17	13175887.72	583.89	747461.08	13175887.70	583.62	0.09	-0.27
FRE-03378	C36	747451.49	13175884.90	583.52	747451.39	13175884.86	583.76	0.11	0.24
FRE-03379	C37	747441.69	13175882.11	583.81	747441.56	13175882.07	583.37	0.14	-0.44
FRE-03380	C38	747432.37	13175879.37	583.40	747432.38	13175879.39	583.03	0.02	-0.37
FRE-03381	C39	747422.81	13175876.41	583.36	747422.98	13175876.47	582.84	0.18	-0.52
FRE-03382	C40	747413.21	13175873.87	583.00	747413.24	13175873.89	582.34	0.03	-0.66
FRE-03383	C41	747404.50	13175870.89	582.53	747404.45	13175870.87	581.78	0.06	-0.75
FRE-03384	C42	747394.36	13175868.03	582.44	747394.20	13175867.98	582.35	0.17	-0.09
FRE-03385	C43	747385.04	13175864.22	584.39	747385.16	13175864.25	583.97	0.12	-0.42
FRE-03386	C44	747374.71	13175861.02	584.70	747374.62	13175860.99	584.68	0.09	-0.02
FRE-03387									

**Table 2**  
**2004/2005 Survey Data - Study Area 2, Imerman Park**  
**Tittabawassee River Bank Erosion Bed Elevation Study**

Location_ID	Location_Desc	2004 Survey Data			2005 Survey Data			2004 vs. 2005	
		Easting	Northing	Elevation	Easting	Northing	Elevation	Station Difference (ft.)	Elev. Difference (ft.)
THT-03400	A1	711806.86	13199434.00	591.43	711806.88	13199434.01	591.42	0.03	-0.01
THT-03401	A2	711802.69	13199431.67	589.83	711802.56	13199431.60	589.72	0.14	-0.11
THT-03402	A3	711798.25	13199429.19	589.15	711798.35	13199429.25	589.07	0.11	-0.08
THT-03403	A4	711793.93	13199426.78	589.27	711793.77	13199426.70	589.36	0.18	0.09
THT-03404	A5	711789.65	13199424.40	589.72	711789.67	13199424.41	589.81	0.02	0.09
THT-03405	A6	711785.28	13199421.95	589.55	711785.30	13199421.97	589.56	0.03	0.01
THT-03406	A7	711780.90	13199419.51	588.89	711780.95	13199419.53	588.83	0.05	-0.06
THT-03407	A8	711776.52	13199417.07	588.59	711776.65	13199417.14	588.65	0.14	0.06
THT-03408	A9	711772.07	13199414.58	589.20	711772.23	13199414.68	589.20	0.19	0.00
THT-03409	A10	711767.83	13199412.22	589.66	711767.84	13199412.22	589.62	0.01	-0.04
THT-03410	A11	711763.31	13199409.69	589.26	711763.45	13199409.77	589.22	0.17	-0.04
THT-03411	A12	711759.01	13199407.30	588.93	711758.96	13199407.27	588.98	0.06	0.05
THT-03412	A13	711754.60	13199404.84	589.20	711754.77	13199404.93	589.07	0.19	-0.13
THT-03413	A14	711750.18	13199402.37	589.28	711750.05	13199402.30	589.36	0.15	0.08
THT-03414	A15	711745.97	13199400.02	589.43	711745.80	13199399.92	589.36	0.20	-0.07
THT-03415	A16	711741.40	13199397.47	588.85	711741.33	13199397.43	588.72	0.08	-0.13
THT-03416	A17	711737.15	13199395.09	588.16	711737.09	13199395.06	588.11	0.07	-0.05
THT-03417	A18	711732.73	13199392.63	588.44	711732.85	13199392.70	588.47	0.14	0.03
THT-03418	A19	711728.30	13199390.16	588.98	711728.21	13199390.11	588.94	0.11	-0.04
THT-03419	A21	711718.46	13199384.66	588.90	711718.57	13199384.73	589.00	0.13	0.10
THT-03420	A22 TOE	711716.49	13199383.57	589.48	711716.43	13199383.53	589.40	0.07	-0.08
THT-03421	A23	711714.80	13199382.63	590.00	711714.74	13199382.59	590.03	0.08	0.03
THT-03422	A24 TB	711712.65	13199381.42	590.76	711712.75	13199381.48	590.63	0.12	-0.13
THT-03423	A25	711710.51	13199380.23	590.45	711710.37	13199380.15	590.53	0.16	0.08
THT-03424	A26	711708.51	13199379.11	589.62	711710.59	13199380.27	590.55	2.38	0.93
THT-03425	A27	711706.41	13199377.94	588.64	711706.48	13199377.98	588.75	0.08	0.11
THT-03426	A28	711704.51	13199376.88	587.59	711704.46	13199376.85	587.57	0.06	-0.02
THT-03427	A29	711702.79	13199375.92	586.16	711702.65	13199375.84	586.15	0.16	-0.01
THT-03428	A30	711701.04	13199374.94	584.96	711700.89	13199374.86	585.12	0.17	0.16
THT-03429	A31	711699.18	13199373.91	583.89	711699.19	13199373.91	584.14	0.01	0.25
THT-03430	A32	711697.29	13199372.85	582.71	711697.26	13199372.84	582.69	0.03	-0.02
THT-03431	A33 H2O EDGE-TOE	711695.93	13199372.09	581.18	711695.95	13199372.11	581.52	0.03	0.34
THT-03432	A34	711694.26	13199371.16	580.09	711694.34	13199371.20	580.90	0.09	0.81
THT-03433	A35	711685.42	13199366.23	578.09	711685.25	13199366.13	578.97	0.20	0.88
THT-03434	A36	711676.53	13199361.26	576.39	711676.63	13199361.32	577.52	0.12	1.13
THT-03435	A37	711667.85	13199356.42	575.41	711667.88	13199356.44	575.77	0.04	0.36
THT-03436	A38	711659.08	13199351.53	575.02	711659.14	13199351.62	575.69	0.11	0.67
THT-03437	A39	711650.30	13199346.63	575.30	711650.15	13199346.61	575.86	0.15	0.56
THT-03438	A40	711641.46	13199341.70	575.09	711641.63	13199341.79	574.93	0.19	-0.16
THT-03439	A41	711632.72	13199336.82	574.82	711632.60	13199336.75	574.43	0.13	-0.39
THT-03440	A42	711624.10	13199332.00	574.14	711624.01	13199331.95	573.99	0.10	-0.15
THT-03441	A43	711615.38	13199327.14	573.58	711615.26	13199327.07	572.91	0.14	-0.67
THT-03442	A44	711606.72	13199322.31	573.39	711606.78	13199322.34	572.67	0.06	-0.72
THT-03443	A45	711597.93	13199317.40	573.27	711598.08	13199317.48	572.74	0.17	-0.53
THT-03444	A46	711589.04	13199312.44	573.45	711588.89	13199312.35	573.03	0.18	-0.42
THT-03445	A47	711580.38	13199307.61	573.36	711580.34	13199307.58	573.01	0.04	-0.35
THT-03446	A48	711571.64	13199302.73	573.30	711571.75	13199302.79	572.63	0.13	-0.67
THT-03447	A49	711562.91	13199297.85	572.97	711562.89	13199297.84	572.23	0.02	-0.74
THT-03448	A50	711554.13	13199292.95	573.55	711554.10	13199292.94	573.48	0.03	-0.07
THT-03449	A51	711545.33	13199288.04	578.69	711545.43	13199288.09	578.75	0.11	0.06
THT-03450	SA2 A H2O EDGE	711543.15	13199286.80	581.27	711542.68	13199286.54	581.48	0.53	0.21
THT-03452	SA2 C1	711781.09	13199476.07	592.35	711780.98	13199476.00	592.40	0.13	0.05
THT-03453	C2	711767.20	13199468.31	587.60	711767.24	13199468.34	587.67	0.05	0.07
THT-03454	C3	711762.83	13199465.88	587.74	711762.92	13199465.93	587.73	0.11	-0.01
THT-03455	C4	711758.43	13199463.42	587.93	711758.63	13199463.46	587.87	0.20	-0.06
THT-03456	C5	711754.10	13199461.00	587.74	711754.09	13199461.00	587.78	0.01	0.04
THT-03457	C6	711749.81	13199458.61	587.87	711749.89	13199458.66	587.90	0.10	0.03
THT-03458	C7	711745.63	13199456.28	587.98					

**Table 2**  
**2004/2005 Survey Data - Study Area 2, Imerman Park**  
**Tittabawassee River Bank Erosion Bed Elevation Study**

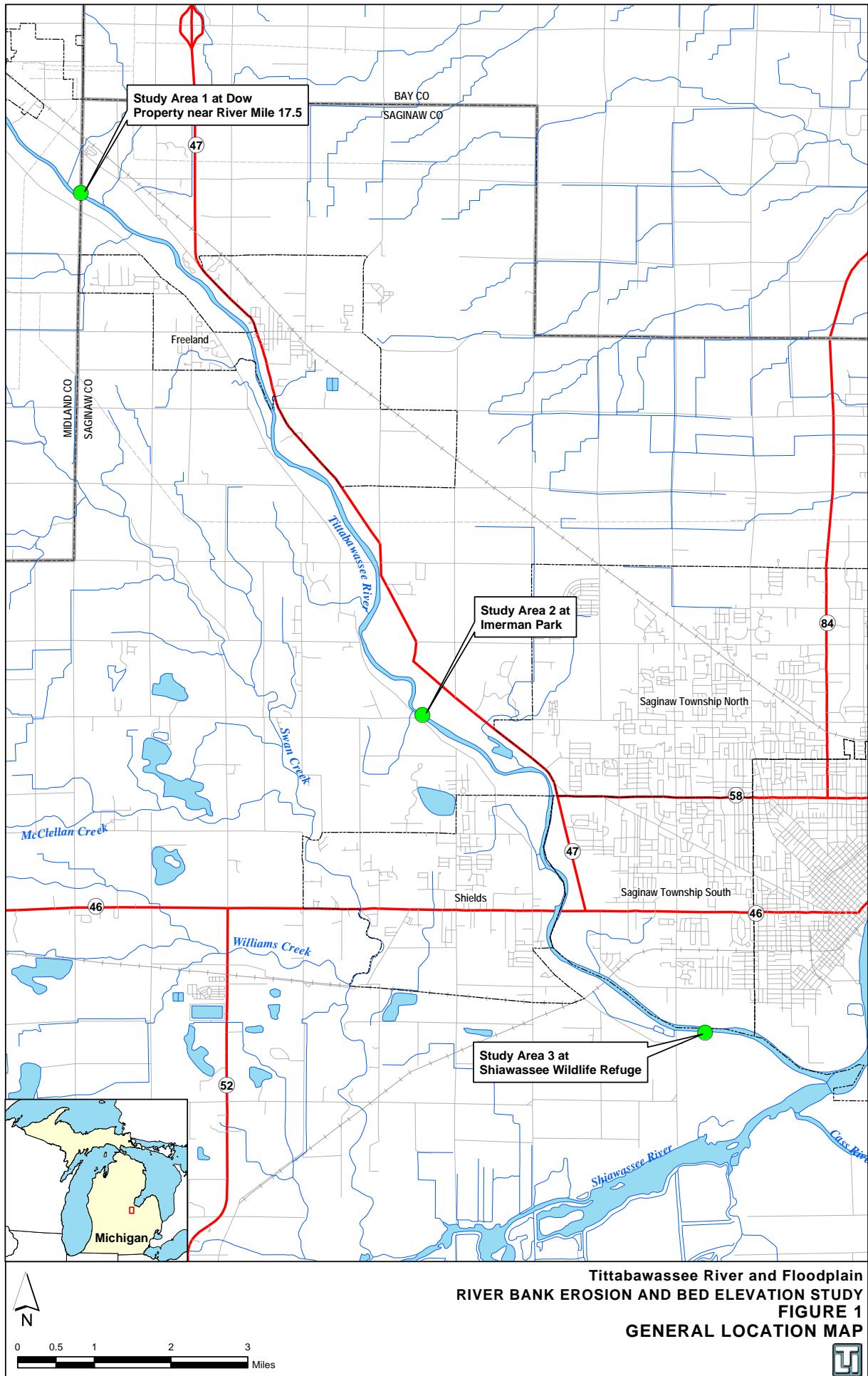
Location_ID	Location_Desc	2004 Survey Data			2005 Survey Data			2004 vs. 2005	
		Easting	Northing	Elevation	Easting	Northing	Elevation	Station Difference (ft.)	Elev. Difference (ft.)
THT-03483	C32	711651.25	13199403.61	576.35	711651.08	13199403.51	576.94	0.20	0.59
THT-03484	C33	711642.49	13199398.72	576.16	711642.57	13199398.76	576.35	0.09	0.19
THT-03485	C34	711633.75	13199393.84	575.80	711633.55	13199393.83	575.74	0.20	-0.06
THT-03486	C35	711625.09	13199389.01	575.66	711625.20	13199389.07	575.40	0.12	-0.26
THT-03487	C36	711616.42	13199384.17	575.53	711616.59	13199384.26	575.12	0.19	-0.41
THT-03488	C37	711607.66	13199379.28	576.78	711607.64	13199379.27	576.72	0.02	-0.06
THT-03489	C38	711599.01	13199374.45	574.88	711599.00	13199374.44	574.54	0.01	-0.34
THT-03490	C39	711590.29	13199369.59	574.06	711590.12	13199369.48	573.72	0.20	-0.34
THT-03491	C40	711581.63	13199364.76	574.40	711581.78	13199364.83	573.55	0.17	-0.85
THT-03492	C41	711572.96	13199359.92	573.98	711572.81	13199359.83	573.45	0.17	-0.53
THT-03493	C42	711563.31	13199354.53	573.80	711563.43	13199354.60	573.13	0.13	-0.67
THT-03494	C43	711555.50	13199350.17	573.54	711555.40	13199350.12	573.22	0.12	-0.32
THT-03495	C44	711546.56	13199345.19	573.85	711546.71	13199345.27	573.18	0.17	-0.67
THT-03496	C45	711537.75	13199340.27	573.66	711537.65	13199340.21	573.09	0.12	-0.57
THT-03497	C46	711528.86	13199335.31	574.04	711528.90	13199335.33	573.95	0.05	-0.09
THT-03498	C47	711520.08	13199330.41	576.42	711520.09	13199330.42	576.56	0.02	0.14
THT-03499	C48 H2O EDGE	711513.15	13199326.54	581.18	711513.20	13199326.57	581.25	0.06	0.07
THT-03501	B1	711838.07	13199397.38	592.11	711838.19	13199397.45	592.26	0.14	0.15
THT-03502	B1	711833.93	13199395.07	591.02	711833.88	13199395.04	591.06	0.06	0.04
THT-03503	B3	711829.49	13199392.59	589.55	711829.62	13199392.67	589.59	0.16	0.04
THT-03504	B4	711825.03	13199390.11	588.94	711825.20	13199390.20	589.00	0.19	0.06
THT-03505	B5	711820.83	13199387.76	589.57	711820.90	13199387.80	589.72	0.08	0.15
THT-03506	B6	711816.39	13199385.28	589.21	711816.28	13199385.22	589.29	0.13	0.08
THT-03507	B7	711812.02	13199382.85	588.64	711812.00	13199382.84	588.70	0.03	0.06
THT-03508	B8	711807.75	13199380.46	588.59	711807.71	13199380.44	588.70	0.05	0.11
THT-03509	B9	711803.32	13199377.99	588.71	711803.36	13199378.01	588.74	0.04	0.03
THT-03510	B10	711798.95	13199375.55	588.48	711798.78	13199375.46	588.52	0.19	0.04
THT-03511	B11	711794.60	13199373.12	588.70	711794.54	13199373.09	588.76	0.07	0.06
THT-03512	B12	711790.20	13199370.67	588.43	711790.17	13199370.65	588.48	0.04	0.05
THT-03513	B13	711785.92	13199368.28	588.21	711785.79	13199368.21	588.27	0.15	0.06
THT-03514	B14	711781.50	13199365.81	587.93	711781.45	13199365.78	588.03	0.06	0.10
THT-03515	B15	711777.02	13199363.31	587.85	711777.02	13199363.31	587.93	0.00	0.08
THT-03516	B16	711772.67	13199360.89	588.11	711772.73	13199360.92	588.15	0.07	0.04
THT-03517	B17	711768.32	13199358.46	587.92	711768.34	13199358.47	587.96	0.02	0.04
THT-03518	B18	711763.94	13199356.01	587.24	711763.78	13199355.93	587.32	0.18	0.08
THT-03519	B19	711759.61	13199353.60	587.16	711759.54	13199353.56	587.30	0.08	0.14
THT-03520	B20	711755.17	13199351.12	587.44	711755.06	13199351.06	587.61	0.13	0.17
THT-03521	B21	711750.92	13199348.75	588.19	711750.89	13199348.73	588.28	0.04	0.09
THT-03522	B22	711743.59	13199344.66	589.23	711743.51	13199344.62	589.42	0.09	0.19
THT-03523	B23 TOE	711740.69	13199343.04	589.37	711740.76	13199343.08	589.58	0.08	0.21
THT-03524	B24	711738.88	13199342.03	589.81	711738.93	13199342.06	589.97	0.06	0.16
THT-03525	B25	711737.09	13199341.03	590.55	711737.12	13199341.04	590.66	0.03	0.11
THT-03526	B26	711735.31	13199340.04	591.15	711735.47	13199340.12	591.20	0.18	0.05
THT-03527	B27 TB	711733.53	13199339.04	591.56	711733.50	13199339.03	591.69	0.03	0.13
THT-03528	B28 TB	711731.55	13199337.94	591.61	711731.67	13199338.00	591.66	0.13	0.05
THT-03529	B29	711730.11	13199337.14	590.61	711729.99	13199337.07	590.84	0.14	0.23
THT-03530	B30	711728.33	13199336.14	588.46	711728.23	13199336.08	588.95	0.12	0.49
THT-03531	B31	711726.68	13199335.22	587.09	711726.71	13199335.24	587.35	0.04	0.26
THT-03532	B32	711725.09	13199334.33	585.88	711725.16	13199334.37	586.19	0.09	0.31
THT-03533	B33	711723.35	13199333.36	584.71	711723.35	13199333.36	584.97	0.00	0.26
THT-03534	B34	711721.96	13199332.58	583.86	711721.84	13199332.52	584.27	0.13	0.41
THT-03535	B35	711720.27	13199331.65	582.97	711720.17	13199331.59	582.77	0.12	-0.20
THT-03536	B36 TOE	711718.62	13199330.72	582.22	711718.74	13199330.79	582.15	0.14	-0.07
THT-03537	B37 H2O EDGE	711718.15	13199330.46	581.38	711718.14	13199330.46	581.71	0.01	0.33
THT-03538	B40	711714.65	13199328.51	579.66	711714.76	13199328.57	579.89	0.12	0.23
THT-03539	B41	711706.03	13199323.69	576.90	711705.88	13199323.61	578.52	0.17	1.62
THT-03540	B42	711697.44	13199318.90	575.82	711697.32	13199318.84	577.58	0.13	1.76
THT-03541	B43	711688.65	13199313.99	574					

**Table 3**  
**2004/2005 Survey Data - Study Area 3, Shiawassee Wildlife Refuge**  
**Tittabawassee River Bank Erosion Bed Elevation Study**

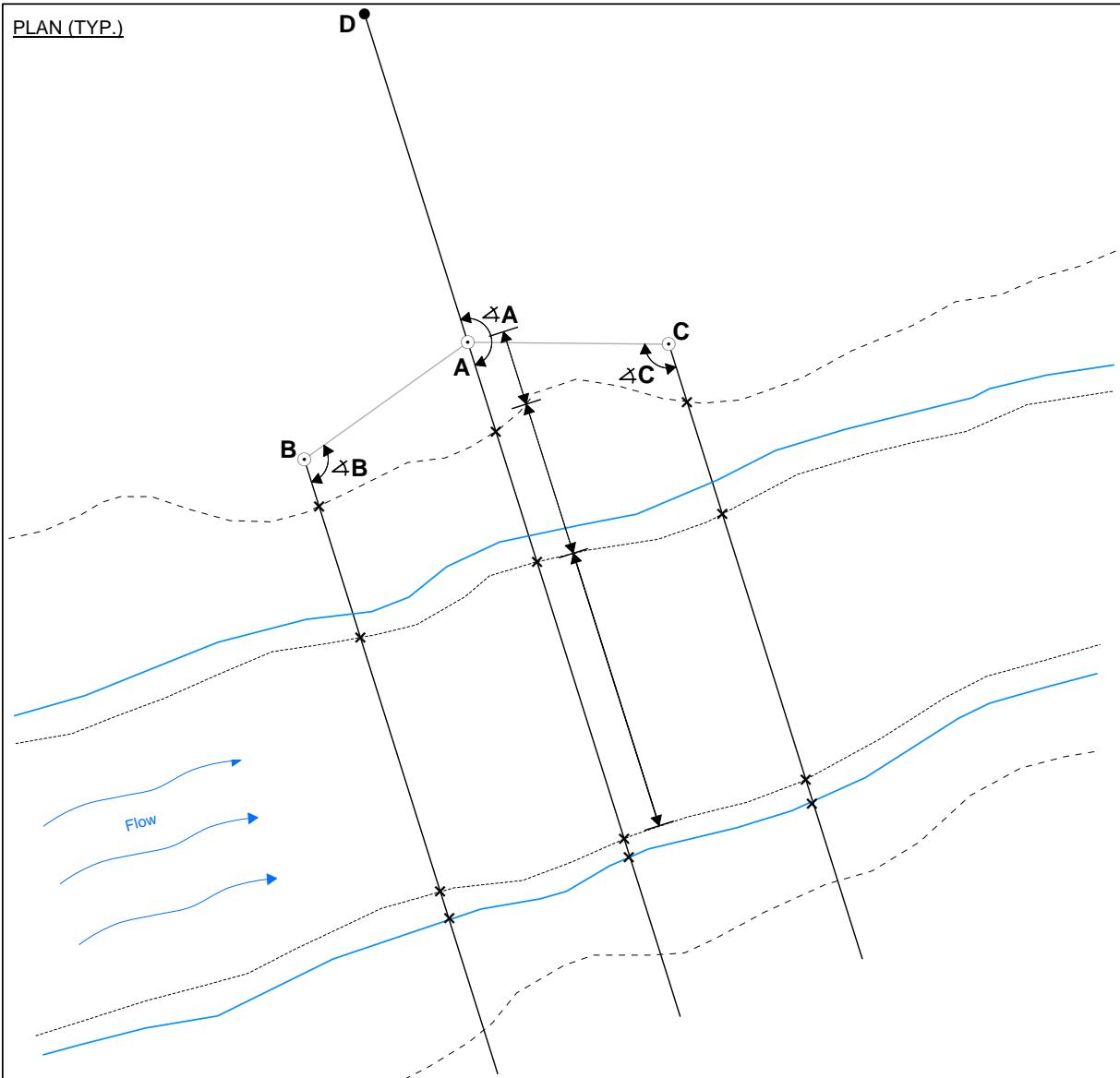
Location_ID	Location_Desc	2004 Survey Data			2005 Survey Data			2004 vs. 2005	
		Easting	Northing	Elevation	Easting	Northing	Elevation	Station Difference (ft.)	Elev. Difference (ft.)
SHI-03562	A1	689916.42	13218821.60	588.13	689916.53	13218821.61	588.18	0.11	0.05
SHI-03563	A2 TB	689919.36	13218821.79	587.70	689919.29	13218821.79	587.81	0.07	0.11
SHI-03564	A3 TOE	689923.33	13218822.05	586.18	689923.34	13218822.05	586.31	0.01	0.13
SHI-03565	A4	689926.33	13218822.25	586.11	689926.42	13218822.26	586.20	0.09	0.09
SHI-03566	A5	689931.23	13218822.57	586.29	689931.33	13218822.58	586.34	0.10	0.05
SHI-03567	A6 TOP	689937.36	13218822.97	586.49	689937.41	13218822.97	586.42	0.05	-0.07
SHI-03568	A7	689938.70	13218823.05	584.23	689938.63	13218823.05	584.67	0.07	0.44
SHI-03569	A8	689940.83	13218823.19	582.94	689940.67	13218823.18	583.42	0.16	0.48
SHI-03570	A9	689942.74	13218823.32	582.09	689942.74	13218823.32	582.41	0.00	0.32
SHI-03571	A10	689944.83	13218823.45	581.46	689944.63	13218823.44	581.70	0.20	0.24
SHI-03572	A11	689946.80	13218823.58	580.91	689946.88	13218823.59	581.15	0.08	0.24
SHI-03573	A12	689948.74	13218823.71	580.33	689948.57	13218823.69	580.51	0.17	0.18
SHI-03574	A13	689950.81	13218823.84	579.83	689950.81	13218823.84	579.94	0.00	0.11
SHI-03575	A14	689952.76	13218823.97	579.36	689952.83	13218823.97	579.34	0.07	-0.02
SHI-03576	A15	689954.91	13218824.11	578.93	689954.77	13218824.10	578.94	0.14	0.01
SHI-03577	A16	689956.99	13218824.24	578.49	689956.81	13218824.23	578.65	0.18	0.16
SHI-03578	A17 H2O EDGE	689959.46	13218824.41	578.22	689950.49	13218823.82	579.99	8.99	1.77
SHI-03579	A18	689971.42	13218825.18	576.45	689971.58	13218825.19	576.49	0.16	0.04
SHI-03580	A19	689981.62	13218825.86	574.65	689981.70	13218825.85	574.40	0.08	-0.25
SHI-03581	A20	689991.56	13218826.49	572.27	689991.55	13218826.49	572.07	0.01	-0.20
SHI-03582	A21	690001.06	13218827.11	572.51	690001.23	13218827.12	572.75	0.17	0.24
SHI-03583	A22	690011.29	13218827.78	572.98	690011.33	13218827.78	573.14	0.04	0.16
SHI-03584	A23	690021.44	13218828.44	573.36	690021.35	13218828.43	573.24	0.09	-0.12
SHI-03585	A24	690031.43	13218829.09	573.15	690031.41	13218829.09	573.09	0.02	-0.06
SHI-03586	A25	690041.47	13218829.74	573.29	690041.64	13218829.75	573.50	0.17	0.21
SHI-03587	A26	690051.37	13218830.39	574.29	690051.39	13218830.39	574.03	0.02	-0.26
SHI-03588	A27	690061.26	13218831.03	574.30	690061.10	13218831.02	574.01	0.16	-0.29
SHI-03589	A28	690071.14	13218831.67	574.21	690071.10	13218831.67	574.00	0.04	-0.21
SHI-03590	A29	690081.04	13218832.32	574.17	690081.05	13218832.32	573.87	0.01	-0.30
SHI-03591	A30	690091.14	13218832.97	574.29	690091.23	13218832.98	574.05	0.09	-0.24
SHI-03592	A31	690101.14	13218833.63	574.28	690101.08	13218833.62	574.13	0.06	-0.15
SHI-03593	A32	690111.06	13218834.27	574.25	690110.88	13218834.26	574.24	0.18	-0.01
SHI-03594	A33	690121.00	13218834.92	574.27	690121.06	13218834.92	574.25	0.06	-0.02
SHI-03595	A34	690131.01	13218835.57	574.44	690131.16	13218835.58	574.12	0.15	-0.32
SHI-03596	A35	690140.89	13218836.21	574.44	690140.95	13218836.22	574.32	0.06	-0.12
SHI-03597	A36	690150.93	13218836.86	574.54	690151.02	13218836.87	574.30	0.09	-0.24
SHI-03598	A37	690160.91	13218837.51	574.44	690160.94	13218837.52	574.17	0.03	-0.27
SHI-03599	A38	690170.86	13218838.16	574.17	690170.80	13218838.16	574.15	0.06	-0.02
SHI-03600	A39	690180.81	13218838.81	574.13	690180.77	13218838.81	574.28	0.04	0.15
SHI-03601	A40	690190.84	13218839.46	573.90	690190.93	13218839.47	574.13	0.09	0.23
SHI-03602	A41	690200.89	13218840.12	574.11	690200.84	13218840.11	574.00	0.05	-0.11
SHI-03603	A42	690210.82	13218840.76	574.34	690210.65	13218840.75	573.96	0.17	-0.38
SHI-03604	A43	690220.83	13218841.42	574.38	690220.77	13218841.41	574.19	0.07	-0.19
SHI-03605	A44	690230.83	13218842.07	574.60	690230.82	13218842.07	574.33	0.02	-0.27
SHI-03606	A45	690240.82	13218842.72	574.33	690240.74	13218842.71	574.12	0.08	-0.21
SHI-03607	A46	690250.74	13218843.36	574.08	690250.77	13218843.37	572.91	0.03	-1.17
SHI-03608	A47	690260.67	13218844.01	576.97	690260.53	13218844.00	575.80	0.14	-1.17
SHI-03609	A48 H2O EDGE	690265.29	13218844.31	578.26	690265.28	13218844.31	577.78	0.01	-0.48
SHI-03611	C1	689907.57	13218887.30	587.51	689907.70	13218887.31	587.53	0.13	0.02
SHI-03612	C2	689912.48	13218887.62	586.83	689912.64	13218887.63	586.98	0.16	0.15
SHI-03613	C3	689917.52	13218887.95	586.09	689917.60	13218887.96	586.22	0.08	0.13
SHI-03614	C4	689922.46	13218888.27	585.09	689922.57	13218888.28	585.25	0.11	0.16
SHI-03615	C5	689927.42	13218888.60	585.22	689927.40	13218888.60	585.35	0.02	0.13
SHI-03616	C6	689932.45	13218888.92	585.74	689932.27	13218888.91	585.91	0.18	0.17
SHI-03617	C7 TB	689934.22	13218889.04	585.57	689934.29	13218889.04	585.56	0.07	-0.01
SHI-03618	C8	689936.58	13218889.19	583.65	689936.62	13218889.20	583.96	0.04	0.31
SHI-03619	C9	689938.36	13218889.31	582.26	689938.44	13218889.31	582.57	0.08	0.31
SHI-									

**Table 3**  
**2004/2005 Survey Data - Study Area 3, Shiawassee Wildlife Refuge**  
**Tittabawassee River Bank Erosion Bed Elevation Study**

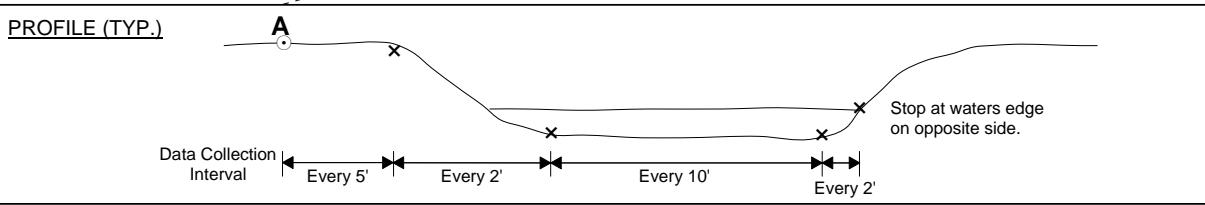
Location_ID	Location_Desc	2004 Survey Data			2005 Survey Data			2004 vs. 2005	
		Easting	Northing	Elevation	Easting	Northing	Elevation	Station Difference (ft.)	Elev. Difference (ft.)
SHI-03645	C35	690152.14	13218903.23	573.95	690152.32	13218903.23	574.03	0.18	0.08
SHI-03646	C36	690162.10	13218903.87	573.68	690162.20	13218903.87	573.82	0.10	0.14
SHI-03647	C37	690172.07	13218904.52	574.00	690172.00	13218904.51	573.89	0.07	-0.11
SHI-03648	C38	690182.06	13218905.17	573.88	690182.01	13218905.17	573.94	0.05	0.06
SHI-03649	C39	690192.01	13218905.82	574.08	690192.20	13218905.83	573.98	0.19	-0.10
SHI-03650	C40	690201.97	13218906.46	574.11	690201.89	13218906.46	573.89	0.08	-0.22
SHI-03651	C41	690211.94	13218907.12	573.86	690211.78	13218907.10	574.50	0.16	0.64
SHI-03652	C42	690221.95	13218907.77	573.75	690222.00	13218907.77	573.76	0.05	0.01
SHI-03653	C43	690231.93	13218908.42	573.91	690232.04	13218908.43	573.79	0.11	-0.12
SHI-03654	C44	690241.94	13218909.07	575.07	690242.06	13218909.08	575.04	0.12	-0.03
SHI-03655	C45	690251.98	13218909.72	575.28	690251.96	13218909.72	575.29	0.02	0.01
SHI-03656	C46 H2O EDGE	690260.89	13218910.30	578.28	690261.07	13218910.32	577.91	0.18	-0.37
SHI-03658	B1	689921.12	13218760.56	588.02	689921.07	13218760.56	588.17	0.05	0.15
SHI-03659	B2	689926.06	13218760.89	587.58	689926.15	13218760.89	587.64	0.09	0.06
SHI-03660	B3	689931.07	13218761.21	587.80	689931.25	13218761.22	587.97	0.18	0.17
SHI-03661	B4	689936.06	13218761.54	587.87	689936.20	13218761.55	588.01	0.14	0.14
SHI-03662	B5	689940.98	13218761.86	588.05	689940.94	13218761.85	588.11	0.04	0.06
SHI-03663	B6 TB	689944.60	13218762.09	587.45	689944.74	13218762.10	587.31	0.14	-0.14
SHI-03664	B7	689946.44	13218762.21	583.88	689946.43	13218762.21	583.64	0.01	-0.24
SHI-03665	B8	689948.35	13218762.34	581.81	689948.22	13218762.33	581.48	0.13	-0.33
SHI-03666	B9	689950.14	13218762.45	580.32	689950.13	13218762.45	580.26	0.01	-0.06
SHI-03667	B10	689952.01	13218762.57	579.74	689952.19	13218762.59	579.86	0.18	0.12
SHI-03668	B11	689953.87	13218762.70	579.20	689953.70	13218762.68	579.37	0.17	0.17
SHI-03669	B12	689955.92	13218762.83	578.87	689956.08	13218762.84	578.86	0.16	-0.01
SHI-03670	B13	689958.34	13218762.99	578.46	689958.29	13218762.98	578.60	0.05	0.14
SHI-03671	B14 H2O EDGE	689959.48	13218763.06	578.22	689952.02	13218762.57	579.92	7.47	1.70
SHI-03672	B15	689971.55	13218763.85	573.93	689971.50	13218763.84	574.42	0.05	0.49
SHI-03673	B16	689981.33	13218764.48	572.73	689981.41	13218764.49	572.35	0.09	-0.38
SHI-03674	B17	689991.33	13218765.13	573.03	689991.33	13218765.13	572.78	0.00	-0.25
SHI-03675	B18	690001.68	13218765.81	573.04	690001.62	13218765.80	572.71	0.06	-0.33
SHI-03676	B19	690011.42	13218766.44	572.80	690011.50	13218766.45	572.73	0.08	-0.07
SHI-03677	B20	690021.62	13218767.11	573.25	690021.48	13218767.09	573.26	0.14	0.01
SHI-03678	B21	690031.54	13218767.75	573.43	690031.72	13218767.76	573.59	0.18	0.16
SHI-03679	B22	690041.47	13218768.40	573.80	690041.41	13218768.39	573.80	0.06	0.00
SHI-03680	B23	690051.59	13218769.06	574.17	690051.76	13218769.07	573.96	0.17	-0.21
SHI-03681	B24	690061.48	13218769.70	574.37	690061.54	13218769.70	574.14	0.06	-0.23
SHI-03682	B25	690070.89	13218770.31	574.47	690071.02	13218770.32	574.15	0.13	-0.32
SHI-03683	B26	690081.44	13218771.00	574.54	690081.38	13218771.00	574.32	0.06	-0.22
SHI-03684	B27	690091.47	13218771.65	574.46	690091.58	13218771.66	574.22	0.11	-0.24
SHI-03685	B28	690101.37	13218772.29	574.53	690101.37	13218772.30	574.14	0.01	-0.39
SHI-03686	B29	690111.23	13218772.94	574.34	690111.11	13218772.93	574.24	0.12	-0.10
SHI-03687	B30	690121.31	13218773.59	574.55	690121.31	13218773.58	574.07	0.01	-0.48
SHI-03688	B31	690131.20	13218774.24	574.54	690131.22	13218774.23	574.19	0.02	-0.35
SHI-03689	B32	690141.25	13218774.89	574.56	690141.29	13218774.89	574.16	0.04	-0.40
SHI-03690	B33	690151.02	13218775.53	574.52	690150.94	13218775.51	574.36	0.08	-0.16
SHI-03691	B34	690161.37	13218776.20	574.59	690161.28	13218776.19	574.30	0.09	-0.29
SHI-03692	B35	690171.16	13218776.84	574.68	690171.23	13218776.84	574.40	0.07	-0.28
SHI-03693	B36	690181.17	13218777.49	575.00	690181.26	13218777.49	574.28	0.09	-0.72
SHI-03694	B37	690191.14	13218778.14	575.10	690191.07	13218778.13	574.68	0.07	-0.42
SHI-03695	B38	690201.09	13218778.78	575.07	690201.02	13218778.78	574.63	0.07	-0.44
SHI-03696	B39	690211.14	13218779.45	574.71	690211.26	13218779.45	574.64	0.12	-0.07
SHI-03697	B40	690221.13	13218780.09	574.71	690221.17	13218780.09	574.45	0.04	-0.26
SHI-03698	B41	690231.09	13218780.74	574.32	690230.94	13218780.72	574.32	0.15	0.00
SHI-03699	B42	690240.93	13218781.38	574.41	690241.00	13218781.38	574.24	0.07	-0.17
SHI-03700	B43	690250.93	13218782.03	575.28	690250.76	13218782.02	575.18	0.17	-0.10
SHI-03701	B44	690260.92	13218782.68	575.81	690260.81	13218782.67	575.76	0.11	-0.05
SHI-03702	B45	690270.84	13218783.32	577.44	690270.83	13218783.32	577.51	0.01	0.07



## PLAN (TYP.)



## PROFILE (TYP.)



### CONTROL ESTABLISHMENT

Using standard total station survey equipment and software, and holding the vertical and horizontal coordinates for the A and D points, Wade-Trim personnel calculated and recorded the bearing for the A-D line, which is then used for establishing the A transect line for each study area.

While set up over control point A, Wade-Trim also recorded the horizontal and vertical coordinates for control points B and C. From these recorded coordinates, Wade-Trim personnel then established the B and C survey transects parallel to the A transect by setting up over control points B and C, respectively; setting the survey backsight on control point A, and turning the appropriate angle to establish the bearing identical to the A transect bearing. These bearings then became the established transect lines for the B and C transects, respectively.

### ELEVATION SURVEY GUIDE

- Upland of the top of streambank: ground elevations were recorded horizontally at five-foot intervals (approximately).
- From the top of streambank to the toe of bank (underwater): ground elevations were recorded horizontally at two-foot intervals (approximately).
- Instream (toe to toe): streambed elevations were recorded horizontally at ten-foot intervals.
- From toe of opposite bank to waters edge (opposite shore): Elevations were recorded horizontally at 2' intervals (approximately).

### LEGEND

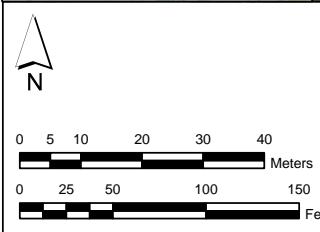
- River Edge
- - - Top of Bank
- - - - Toe of Bank
- 36" Concrete Monument
- 18" Rebar w/ Survey Cap

### Tittabawassee River and Floodplain

### RIVER BANK EROSION AND BED ELEVATION STUDY

**FIGURE 2  
TYPICAL GROUND CONTROL**





Tittabawassee River and Floodplain  
RIVER BANK EROSION AND BED ELEVATION STUDY  
**FIGURE 3**  
**SURVEY POINTS**  
**AT DOW PROPERTY NEAR RIVER MILE 17.5**





LEGEND

● Survey Data Station

Tittabawassee River and Floodplain

RIVER BANK EROSION AND BED ELEVATION STUDY

FIGURE 4  
SURVEY POINTS  
AT IMERMAN PARK



N

0 5 10 20 30 40  
Meters

0 25 50 100 150  
Feet





**LEGEND**

- Survey Data Station

#### Tittabawassee River and Floodplain

#### RIVER BANK EROSION AND BED ELEVATION STUDY

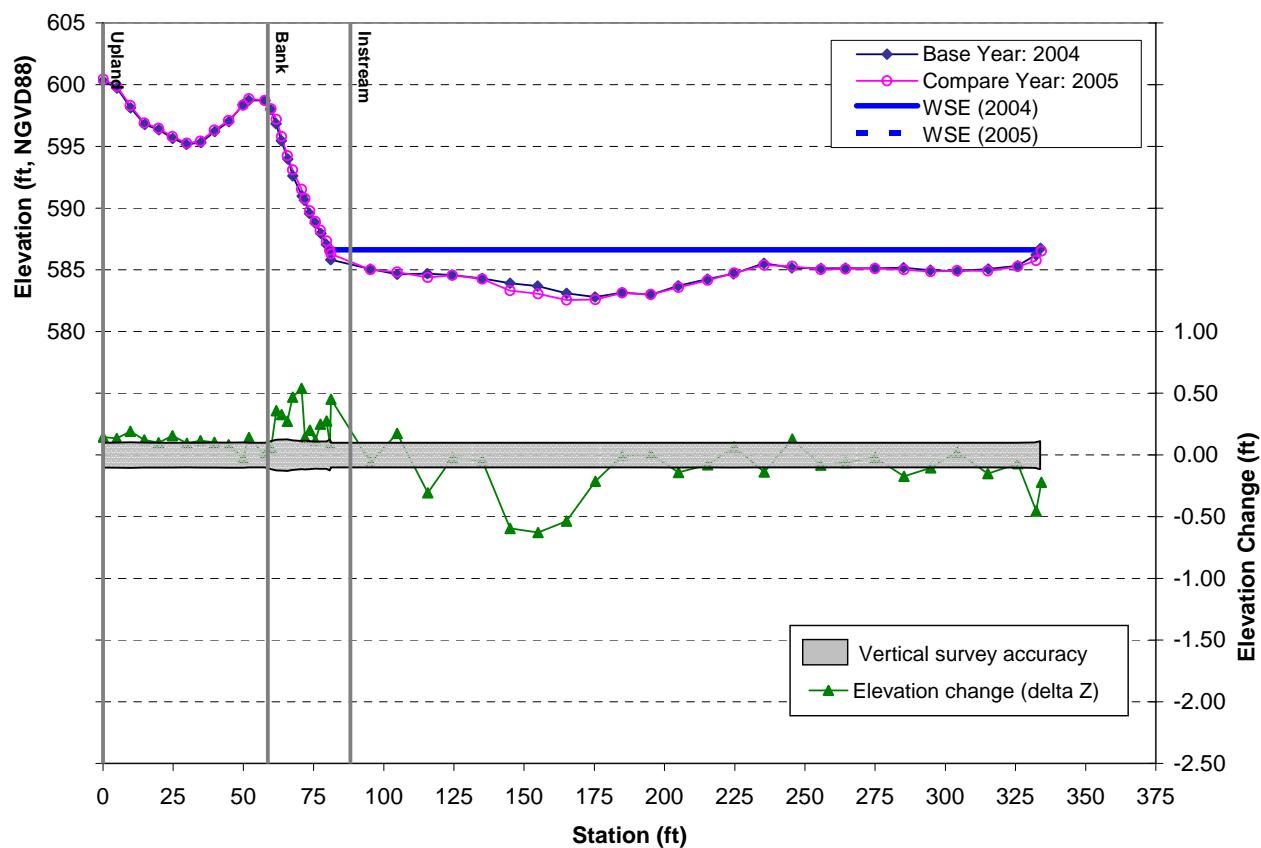
#### FIGURE 5 SURVEY POINTS AT THE SHIAWASSEE WILDLIFE REFUGE



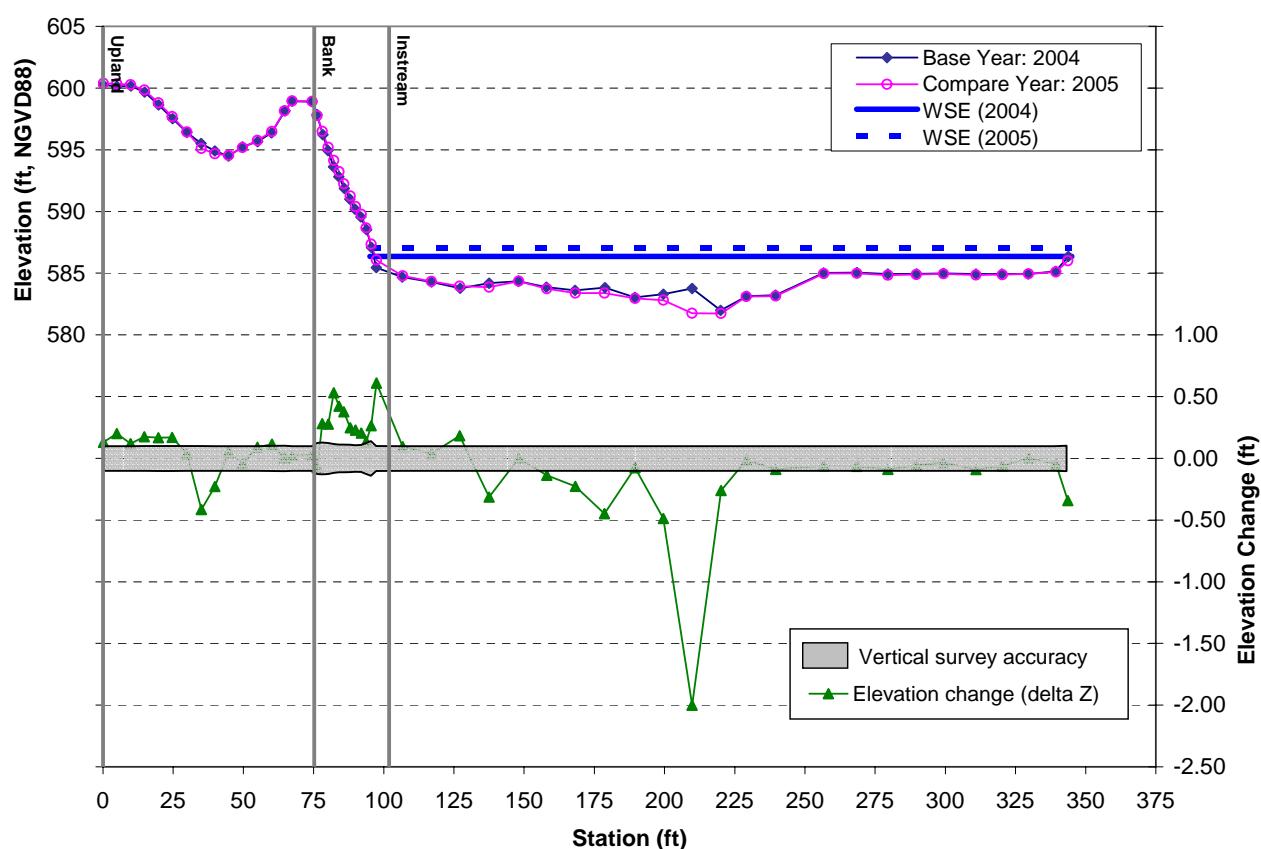
0 5 10 20 30 40  
Meters

0 25 50 100 150  
Feet

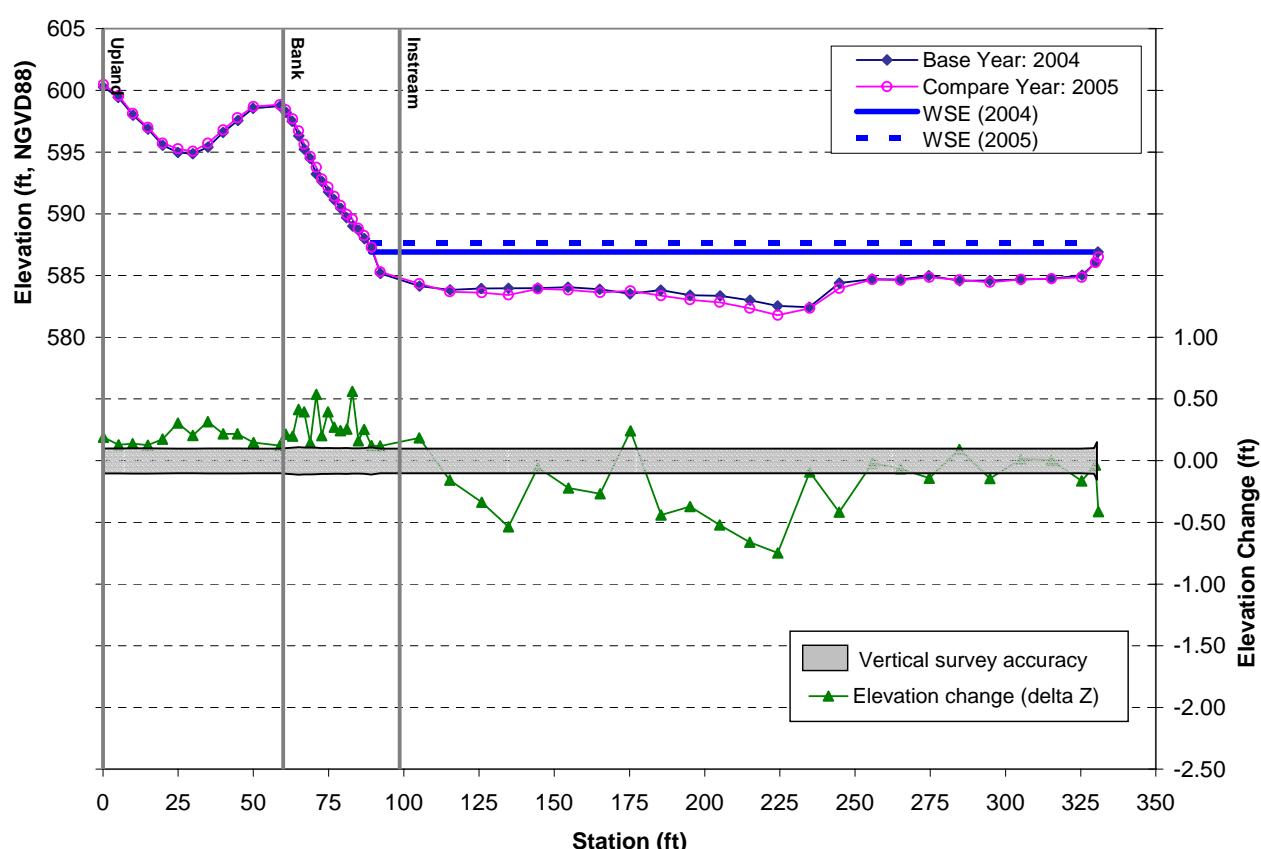




**Transect B (North to South)**

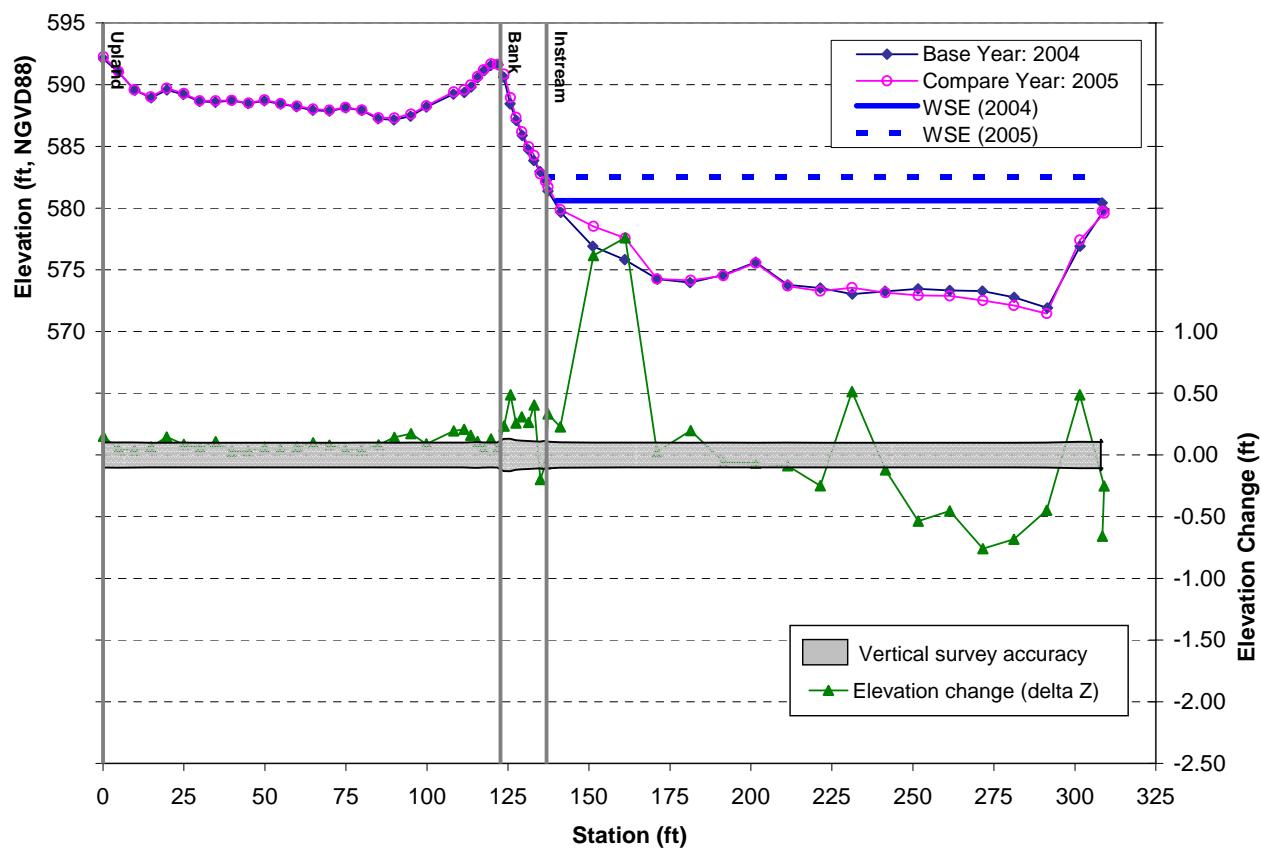


**Transect A (North to South)**

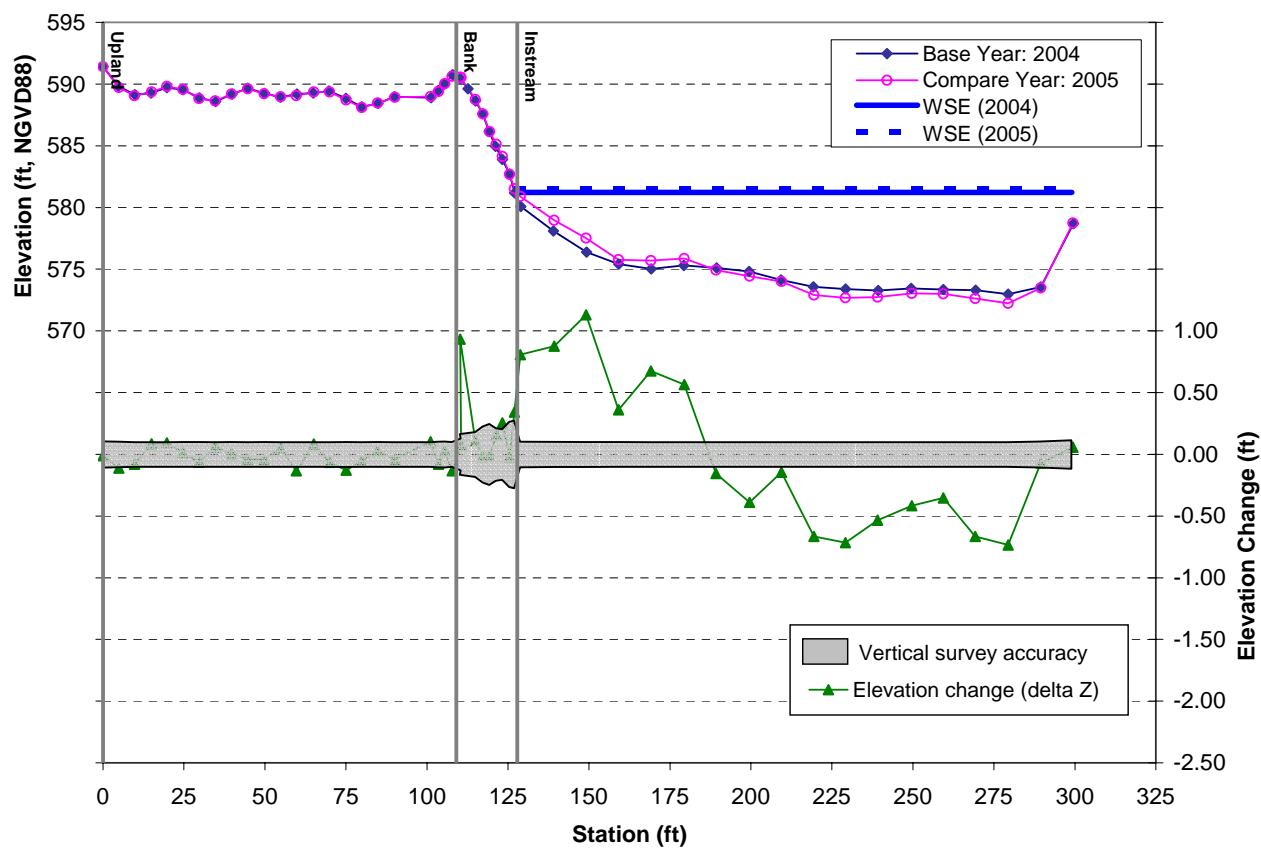


**Transect C (North to South)**

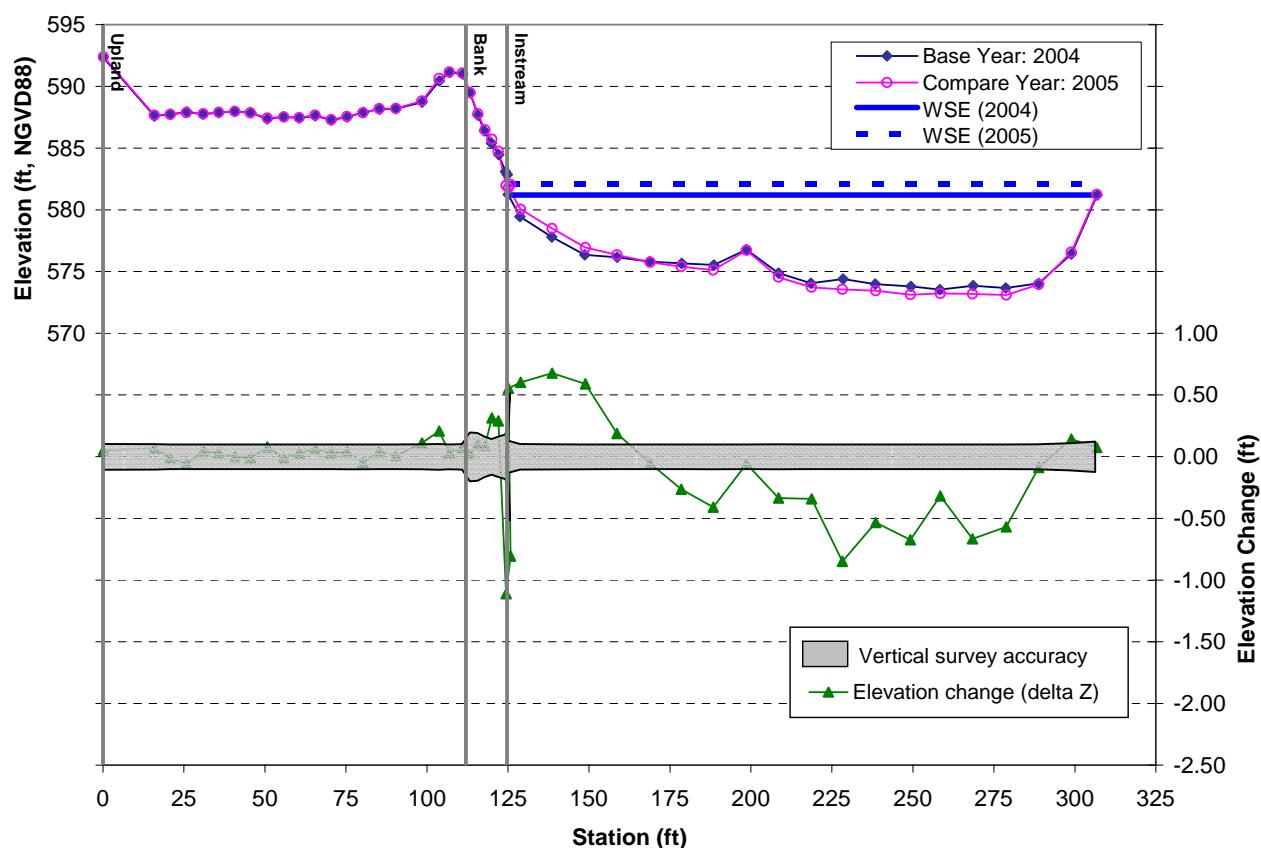
**Figure 6 – Transect Elevation Profiles**  
 Study Area 1 – Dow Property Near Rivermile 17.5  
 Tittabawassee Bank Erosion, Bed Elevation Study



**Transect B (North to South)**

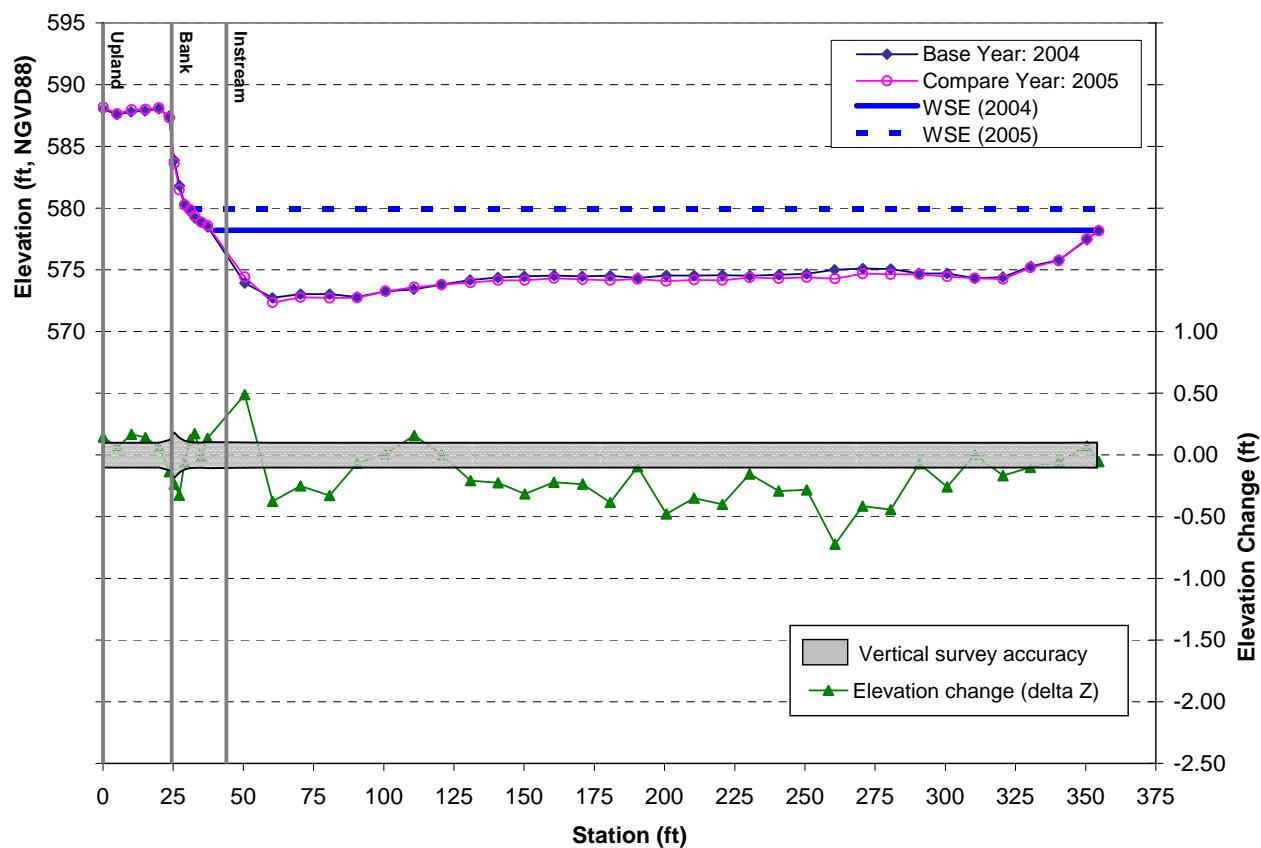


**Transect A (North to South)**

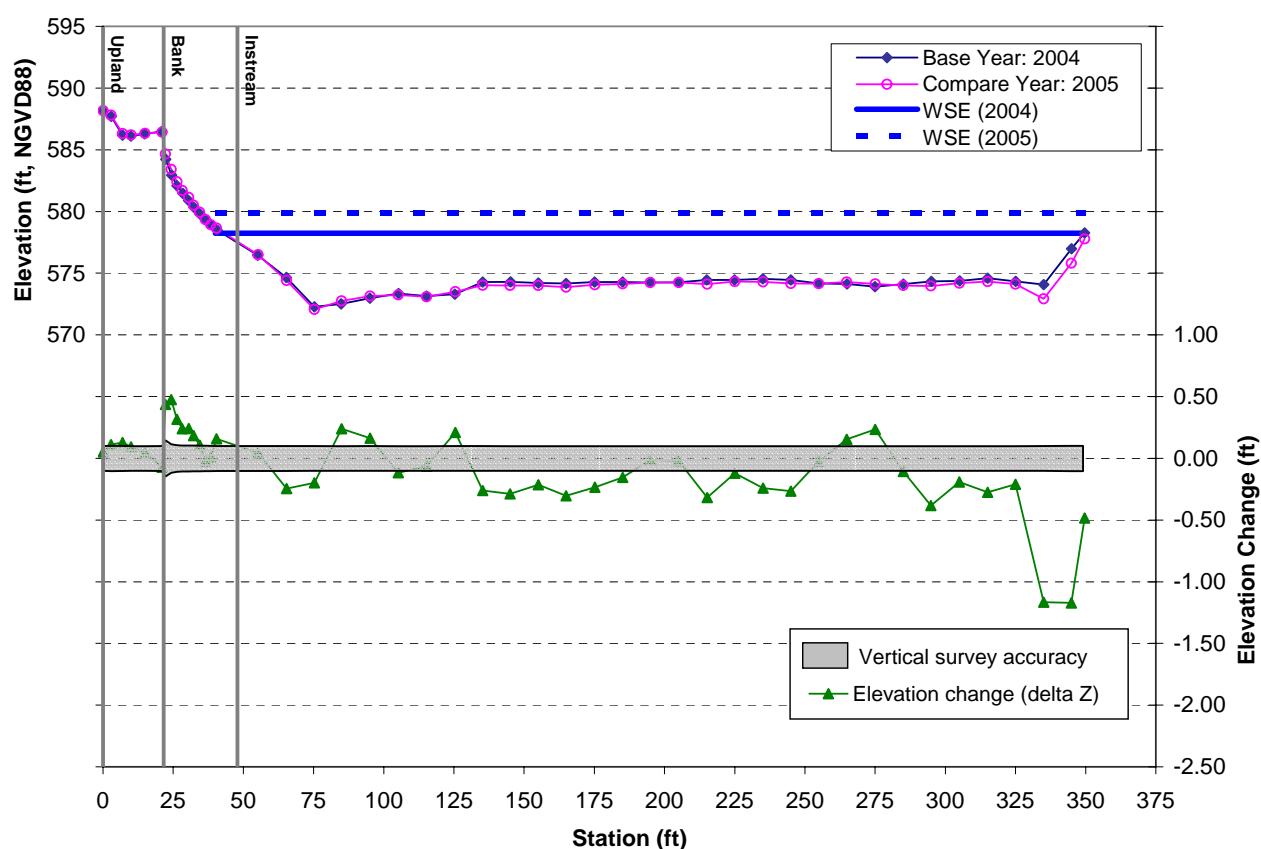


**Transect C (North to South)**

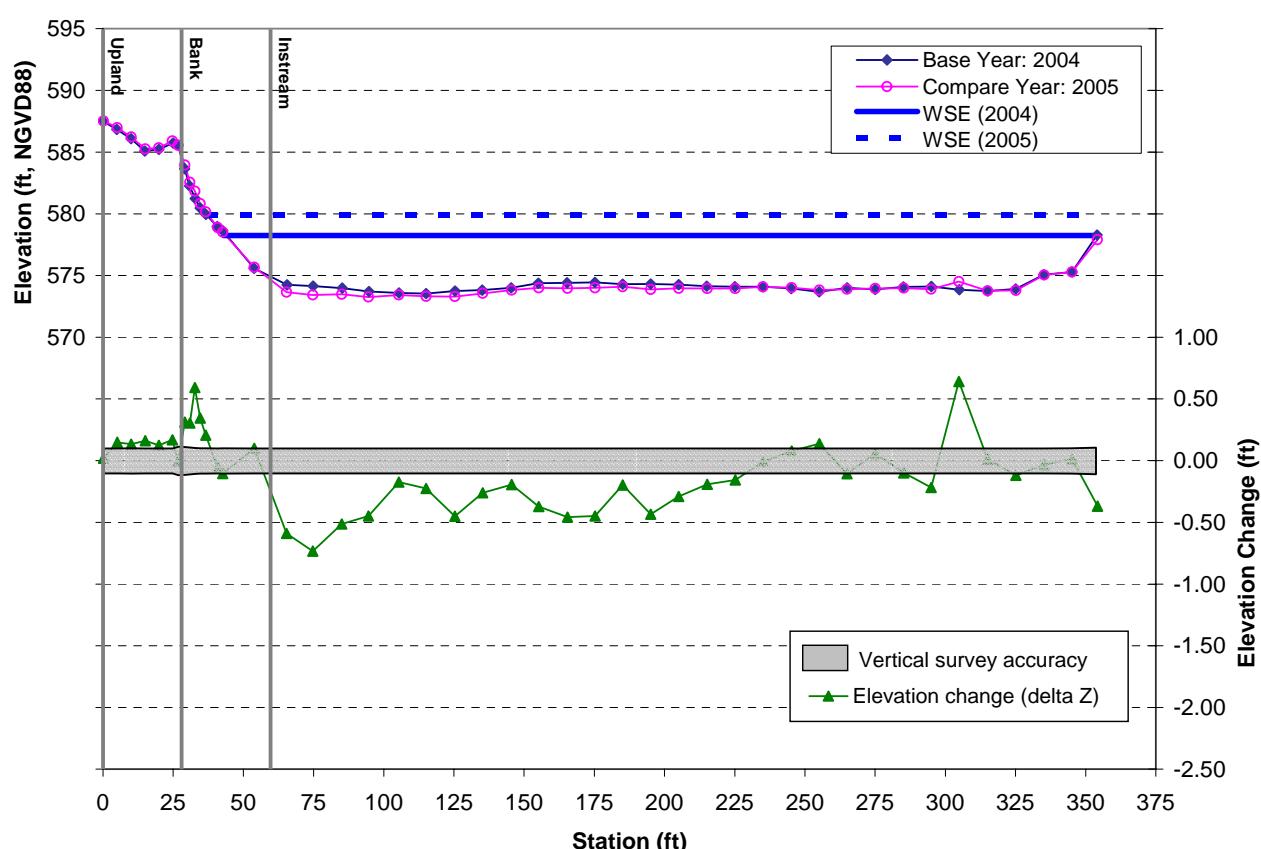
**Figure 7 – Transect Elevation Profiles**  
 Study Area 2 – Imerman Park  
 Tittabawassee River Bank Erosion, Bed Elevation Study



**Transect B (North to South)**



**Transect A (North to South)**



**Transect C (North to South)**

**Figure 8 – Transect Elevation Profiles**  
 Study Area 3 – Shiawassee Wildlife Refuge  
 Tittabawasee River Bank Erosion, Bed Elevation Study